

SDAC-TR-75-9

ADA020315

# THE EFFECT OF BANDPASS FILTERS ON LASA DETECTION PERFORMANCE

ANDRE C. CHANG and RAYMOND M. SEGGEKE

Seismic Data Analysis Center

Teledyne Geotech, 314 Montgomery Street, Alexandria, Virginia 22314

31 JUL 1975

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

Sponsored By

The Defense Advanced Research Projects Agency

Nuclear Monitoring Research Office

1400 Wilson Boulevard, Arlington, Virginia 22209

ARPA Order No. 1620

Monitored By

VELA Seismological Center

312 Montgomery Street, Alexandria, Virginia 22314



Disclaimer: Neither the Defense Advanced Research Projects Agency nor the Air Force Technical Applications Center will be responsible for information contained herein which has been supplied by other organizations or contractors, and this document is subject to later revision as may be necessary. The views and conclusions presented are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency, the Air Force Technical Applications Center, or the US Government.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER <b>SDAC-TR-75-9</b>	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) <b>THE EFFECT OF BANDPASS FILTERS ON LASA DETECTION PERFORMANCE.</b>	5. TYPE OF REPORT & PERIOD COVERED <b>Technical Rept.</b>	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) <b>Chang, Andre C. and Seggelke, Raymond M. Andre C. /Chang Raymond M. /Seggelke</b>	8. CONTRACT OR GRANT NUMBER(s) <b>F08606-76-C-0004</b> <b>ARPA Order-2551</b>	9. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
10. PERFORMING ORGANIZATION NAME AND ADDRESS <b>Teledyne Geotech 314 Montgomery Street Alexandria, Virginia 22314</b>	11. REPORT DATE <b>31 July 1975</b>	12. NUMBER OF PAGES <b>24</b>	13. SECURITY CLASS. (of this report) <b>Unclassified</b>
14. CONTROLLING OFFICE NAME AND ADDRESS <b>Defense Advanced Research Projects Agency Nuclear Monitoring Research Office 1400 Wilson Blvd.-Arlington, Virginia 22209</b>	15. SECURITY CLASS. (of this report) <b>Unclassified</b>	16. DECLASSIFICATION DOWNGRADING SCHEDULE	
17. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) <b>VELA Seismological Center 312 Montgomery Street Alexandria, Virginia 22314</b>	18. DISTRIBUTION STATEMENT (of this Report)  <b>APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.</b>		
19. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
20. SUPPLEMENTARY NOTES			
21. KEY WORDS (Continue on reverse side if necessary and identify by block number)  <div style="display: flex; justify-content: space-between;"> <div> <b>Detection Performance</b>  <b>On-line Testing</b>  <b>SP Detection Filters</b>  <b>Detection Processor</b> </div> <div> <b>LASA Noise Level</b>  <b>Noise Filtering</b> </div> </div>			
22. ABSTRACT (Continue on reverse side if necessary and identify by block number)  <p>On-line testing at the SDAC of short-period automatic detection filters 0.9-1.4 Hz, 0.9-1.8 Hz, 0.8-1.8 Hz, and 0.8-2.5 Hz reveals no statistically significant differences in the number of events reaching the LASA summary bulletin.</p> <p>Almost all detection processor detections which do not reach the summary bulletin are due to multiple picks on regional events. Therefore, a substantial lowering of the analyst workload or a substantially lowered threshold</p>			

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408 258 ✓

VB

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

would be possible if a reliable procedure could be developed for flagging detections due to regional events.

An excellent correlation has been found between the number of events per hour which reach the summary bulletin, and the hourly noise level.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

THE EFFECT OF BANDPASS FILTERS ON LASA DETECTION PERFORMANCE

SEISMIC DATA ANALYSIS CENTER REPORT NO.: SDAC-TR-75-9

AFTAC Project Authorization No.: VELA T/6709/B/ETR

Project Title: Seismic Data Analysis Center

ARPA Order No.: 2551

ARPA Program Code No.: 6F10

Name of Contractor: TELEDYNE GEOTECH

Contract No.: F08606-76-C-0004

Date of Contract: 01 July 1975

Amount of Contract: \$2,319,926

Contract Expiration Date: 30 June 1976

Project Manager: Royal A. Hartenberger  
(703) 836-3882

P. O. Box 334, Alexandria, Virginia 22314

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

ACQUISITION FILE	
NTIS	SEARCHED <input checked="" type="checkbox"/>
DDC	INDEXED <input type="checkbox"/>
UNCLASSIFIED	<input type="checkbox"/>
ACQUISITION	<input type="checkbox"/>
BY	
DATE	
A	

## ABSTRACT

On-line testing at the SDAC of short-period automatic detection filters 0.9-1.4 Hz, 0.9-1.8 Hz, 0.8-1.8 Hz, and 0.8-2.5 Hz reveals no statistically significant differences in the number of events reaching the LASA summary bulletin.

Almost all detection processor detections which do not reach the summary bulletin are due to multiple picks on regional events. Therefore, a substantial lowering of the analyst workload or a substantially lowered threshold would be possible if a reliable procedure could be developed for flagging detections due to regional events.

An excellent correlation has been found between the number of events per hour which reach the summary bulletin, and the hourly noise level.

## TABLE OF CONTENTS

	Page
ABSTRACT	2
INTRODUCTION	5
RESULTS	7
REFERENCES	16
ACKNOWLEDGEMENTS	17
APPENDIX - Noise level, number of detection processor detections, number of events processed by the event processor and number of events published in the daily event summary bulletin for each period.	18

# LIST OF FIGURES

Figure No.	Title	Page
1	Noise level, number of detection processor detections, number of events processed by the event processor and number of events published in the daily event summary bulletin for each day from March 11 through July 25, 1974. Changes in bandpass filter and EP threshold are shown by vertical partition lines.	8
2	Noise level, number of detection processor detections, number of events processed by the event processor, and number of events in the summary bulletin for each hour of the day for the period April 3 through June 12, 1974, during which period Filter 3, 0.8-1.8 Hz was being used.	11
3	Published events per hour as a function of the hourly noise level for the period April 3 through June 12, 1974, during which period Filter 3, 0.8-1.8 Hz was being used.	13
4	Derivative with respect to magnitude of the logarithm of the cumulative recurrence curves constructed from LASA bulletin data in four separate time periods in the interval March 11 through July 25, 1974. A different bandpass filter was used in each of the time periods. Least-squares lines fitted to the recurrence curves in the magnitude interval 4.0-4.8 were used to determine differential detection threshold.	15

## INTRODUCTION

Chiburis et al. (1974a,b) evaluated the effects on the detection performance of LASA produced by discarding outer subarrays and by using only unphased subarray sums to form the full array beams. In this study we evaluate the relative detection performance resulting from the use of different bandpass filters in the LASA on-line detection system at the SDAC. Different filters are of interest because the existing 0.9-1.4 Hz filter severely distorts the signal, and may miss some low or high-frequency events. The detection system has recently been described in detail by Chang (1974), and the following description of the LASA detection system is extracted from that report.

A Short Time Average (STA) is computed by rectifying and integrating each filtered array beam over a period of 1.8 seconds, with the average being renewed every 0.6 seconds. Similarly a Long Time Average (LTA) is computed over approximately 16 STA intervals by exponentially weighting the previous LTA value and adding the current STA value. The detection algorithm performs successive tests every 0.6 second.

There are actually two detection algorithms in parallel. The first is the signal-to-noise ratio (S/N) threshold test which determines the size and duration of the signal. When the ratio STA/LTA exceeds the fixed threshold value of  $N$  dB  $Q$  times out of  $Q'$  consecutive tests, the signal switch is declared "ON" for that beam. After the switch activates, the end of signal arrival is declared when the S/N ratio of the beam becomes lower than the

---

Chang, Andre C., 1974, A comparison of the LASA-NORSAR short period arrays, Teledyne Geotech, SDAC Technical Report 74-5, Alexandria, Virginia. AD 003484

Chiburis, E. F., Ahner, R. O., Chang, A. C., and Kerr, A. U., 1974a, The effect of reduced configurations at LASA on detection signal-to-noise ratios, Teledyne Geotech, SDAC Technical Report 74-7, Alexandria, Virginia. AD A004991

Chiburis, E. F., Ahner, R. O., and Chang, A. C., 1974b, The effects of using unphased subarray sums in LASA beams on the detection performances of the array, Teledyne Geotech, SDAC Technical Report 74-14, Alexandria, Virginia.

turn-off threshold of  $N'$  dB; and the switch is turned "OFF". The turn-on threshold is set to 10 dB, and the turn-off threshold to 7dB. The  $Q/Q'$  parameter is set to 2/2.

The second detection algorithm is the spatial coherency test. This algorithm determines the consistency of the seismic signal in both azimuth and velocity. When a seismic signal arrives at the array, high STA values may be observed in the neighboring beams. The algorithm seeks the maximum STA beam and checks if the previous maximum was found within the distance of  $\Delta U = 2$  beams of the current maximum beam. When this condition is satisfied  $P = 3$  consecutive times, the coherency test is satisfied and the arrival is declared to be on the beam with the highest STA value during these  $P$  consecutive tests. Then the overall algorithm checks if any of these  $P$  beams are "ON". If so, a final "detection" is declared.

The bandpass filter 0.9-1.4 Hz was selected by IBM (1967) on the basis of the signal-to-noise gain achieved in a study of LONGSHOT and a Kamchatka earthquake. The parameter values mentioned above, for  $N$ ,  $N'$ ,  $Q$ ,  $Q'$ ,  $\Delta U$ ,  $P$  have also been selected to go along with this filter. Plausible arguments can be made that other parameter values might be suitable for other filters. For example, a broader passband would result in a more stable STA and therefore lower values might be suitable for detection thresholds. Also, a signal passed through a broader passband might not ring so much so that reduction in  $Q$  and  $Q'$ , together with a reduction in  $N'$  might be suitable.

Despite these arguments, the parameter values mentioned above were not changed in the course of experimenting with the new bandpass filters in order to minimize difficulties in deciding whether any changes in detection rate were due to parameter changes or to filter changes. It is plausible, therefore, that the performance of the filters other than 0.9-1.4 Hz could be improved by careful selection of detection parameters.

---

IBM, August 1967, Third Quarterly Technical Report, Experimental Signal Processing System, ESD-TR-68-149, Gaithersburg, Maryland.

## RESULTS

In Figure 1 we see the noise level, number of detection processor (DP) detections, number of events processed by the event processor (EP), and number of events published in the daily event summary bulletin for each day from March 11 through July 25, 1974. Changes in bandpass filter and EP threshold are shown by vertical partition lines.

The noise level is computed as the average of the LTA values reported at detection time for each of the events on the LASA event tape for the day under consideration. Events on the LASA event tape are, almost exclusively, events which appear on the final summary bulletin.

The EP threshold controls the number of events detected by DP which are allowed to be scrutinized by the analyst.

Examination of the noise trace in Figure 1 shows the sudden changes in amplitude which occurs with the change in filters. There is no perceptible drift, suggesting that seasonal effects are small, as reported by Dean (1972). The means and differences of the means in terms of  $m_b$  are given in Table I for the different time periods.

Row 5 of Table I lists long-term seismic noise values (zero-to-peak) in millimicrons for each filter. The bracketed values represent the change in noise level relative the broadest filter (Column 4) in  $m_b$  units. Row 6 shows corresponding information for rms noise computed over a ten minute sample recorded in June. In this case the data base is common to all filters, and the change in noise levels relative to the broadest filter is about the same as those shown in Row 5 for the broadband noise. This may indicate small seasonal variations in the noise.

---

Dean, W., 1972, A geophysical evaluation of the short-period LASA/SAAC system, SAAC-5, Teledyne Geotech, Alexandria, Virginia. AD 745101

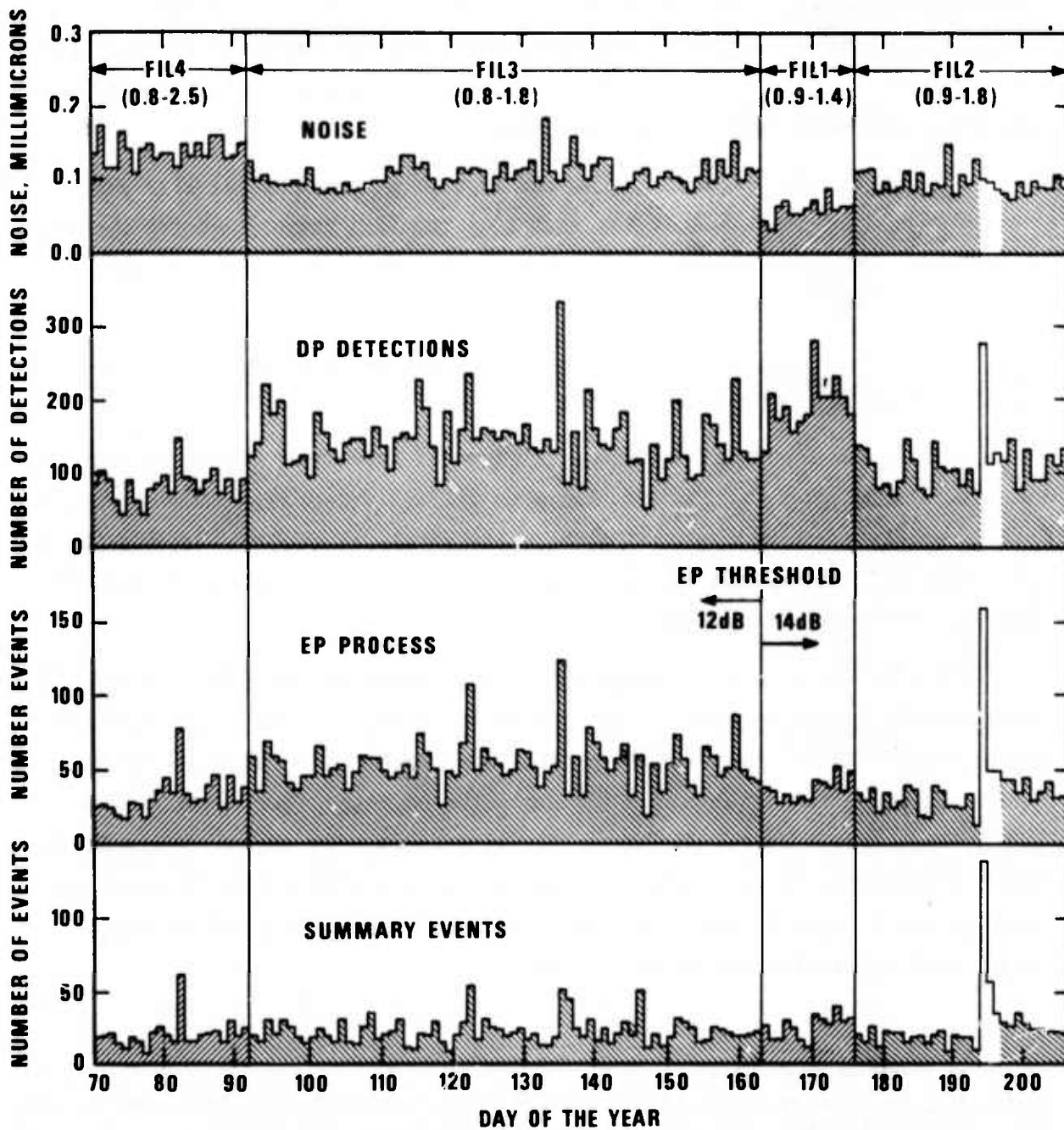


Figure 1. Noise level, number of detection processor detections, number of events processed by the event processor and number of events published in the daily event summary bulletin for each day from March 11 through July 25, 1974. Changes in bandpass filter and EP threshold are shown by vertical partition lines.

TABLE I

## Performance Summary for Different Filters

1	Filter Number	1	2*	3	4
2	Passband	0.9-1.4	0.9-1.8	0.8-1.8	0.8-2.5
3	Days of 1974 in operation	June 13- June 25 164-176	June 26- July 25 177-206	Apr 03- June 12 93-163	Mar 11- Apr 02 70-92
4	Total days of operation	13	30	71	22
5	Long-term zero to peak noise average for all events	0.065 (-0.33)**	0.097 (-0.16)**	0.108 (-0.11)**	0.139
6	10-minute rms noise level, $m_b$	0.056 (-0.31)**	0.064 (-0.26)**	0.080 (-0.16)**	0.115
7	Average DP detections per day	199 $\pm$ 8	107 $\pm$ 5	147 $\pm$ 4	84 $\pm$ 5
8	EP threshold (dB)	14	14	12	12
9	Average EP processed events per day	33 $\pm$ 6	32 $\pm$ 3	54 $\pm$ 4	32 $\pm$ 3
10	Average daily summary events	26 $\pm$ 4 (21.4 $\pm$ .7)	21 $\pm$ 2	22 $\pm$ 2	20 $\pm$ 2
11	Daily summary $\Delta m_b$ if $b = 1.0$	0.11 (0.03)	0.02	0.05	0.0
12	Recurrence curve threshold change 50%	0.14	0.09	0.03	0.0
13	Recurrence curve threshold change 90%	0.19	0.10	0.04	0.0
14	EP/DP %	19	30	37	38
15	Summary/DP %	13	20	15	24
16	Summary/EP %	68	66	41	63

\*Day: 194-196 eliminated due to unusual conditions created by Colombian earthquake.

\*\*Change in noise level relative to Column 4 in  $m_b$  units.

Also in Figure 1 we see the number of DP and EP events together with the number of summary published events. While the DP and EP traces show sudden jumps at the times when the filter changed, no such change is visible for the summary events trace; and this is verified in Table I where we see that the standard deviation of the summary means are large enough so that one could not say with confidence that any of the means are significantly different from each other. The figure in parenthesis for the average summary events per day with Filter 1 (0.9-1.4 Hz) is obtained by averaging the LASA bulletin from January 1, 1974 through April 30, 1975 with the exceptions of March through July 1974.

In Figure 2 we see (for Filter 3, 0.8-1.8 Hz, the experiment of longest duration) the variation with respect to time of day of the noise, DP detections, EP events, and published summary events. Similar figures are given in the Appendix for the other filters. We see that the noise reaches a minimum at local nighttime, where also there is a maximum in the number of events detected by DP. Surprisingly, however, there is another maximum in detected events between 8 a.m. and 4 p.m. Examination of these signals show that they have the character of local and near-regional events, and that the secondary maximum does not occur on Sundays and holidays. We therefore assume that many of them are due to mining activity.

In every DP detection examined thus far from any hour of the day there have been no indications of a truly "random" false alarm. Regional characteristics predominate. Thus it would seem that a substantial lowering of the analyst workload, together with a corresponding lowering of the detection threshold, would be possible if a regional event rejection algorithm could be devised and implemented.

Figure 2c shows the EP processed events together with the detections which were judged by the analysts to be teleseismic in nature and which were included in the summary bulletin. We see that the EP processed events also show the double maximum. This is reasonable since they were selected from the set of DP detections principally by application of a higher threshold together with automatic elimination of multiple picks of the same event. Corresponding figures for the other filters are included in the Appendix and show corresponding features.

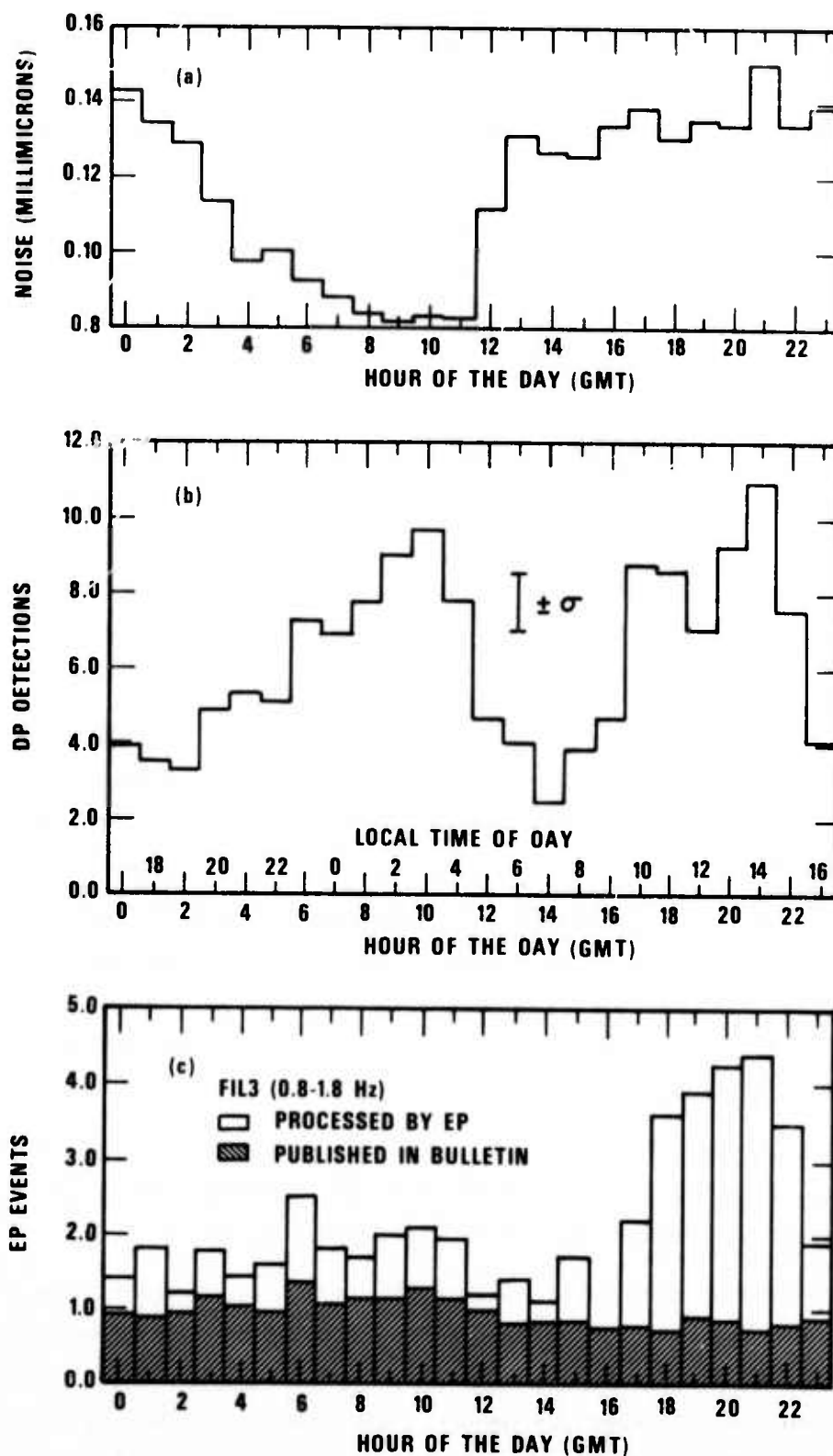


Figure 2. Noise level, number of detection processor detections, number of events processed by the event processor, and number of events in the summary bulletin for each hour of the day for the period April 3 through June 12, 1974, during which period Filter 3, 0.8-1.8 Hz was being used.

On the other hand, the number of events included in the summary bulletin shows no second maximum, indicating that the analysts have successfully removed the local events, including the cultural ones, from the event bulletin.

Figure 3 shows the correlation between hourly noise level and hourly number of events in the event bulletin. The correlation seems excellent and a slope of  $-1.0$ , which would be appropriate for a seismicity magnitude relationship of  $N \sim 10^{-1.0m_b}$  seems to be a good fit.

In Table I we note the variation in number of DP and EP detections with filter passband. It is not quite clear at present why there should be so much smaller a percentage variation in number of EP events as compared to DP events. One possibility is that the regional events have a steeper frequency-magnitude curve than the teleseismic events and therefore a high percentage of small amplitudes comes from this source. Then a small threshold change at low amplitudes will yield a larger percentage change in number of events than the same change at larger amplitudes.

Another possible contributing explanation is that the different filters introduce different amounts of "ringing" which generate different numbers of "multiple picks" per event. Multiple picks are generally eliminated by the EP processor.

Still another possibility is that some of the DP detections are truly random fluctuations whose number increases as the passband narrows due to instability in the STA, combined with a fixed threshold. This possibility is, however, ruled out by the observed absence of DP detections which appear to be random fluctuations.

The dramatic increase in number of EP processed detections as the filter changes from 0.9-1.8 Hz to 0.8-1.8 Hz is presumably due in part to the simultaneous decrease in the EP threshold from 14 to 12 dB.

The most important result of this study is, however, that when one considers the standard errors of the means of the number of summary detections there is no conclusive relative advantage to the use of any of these filters. If we nonetheless take the apparent advantage in number of summary events produced, 21.4 as compared to 20, 21, or 22, one sees in Table I that this

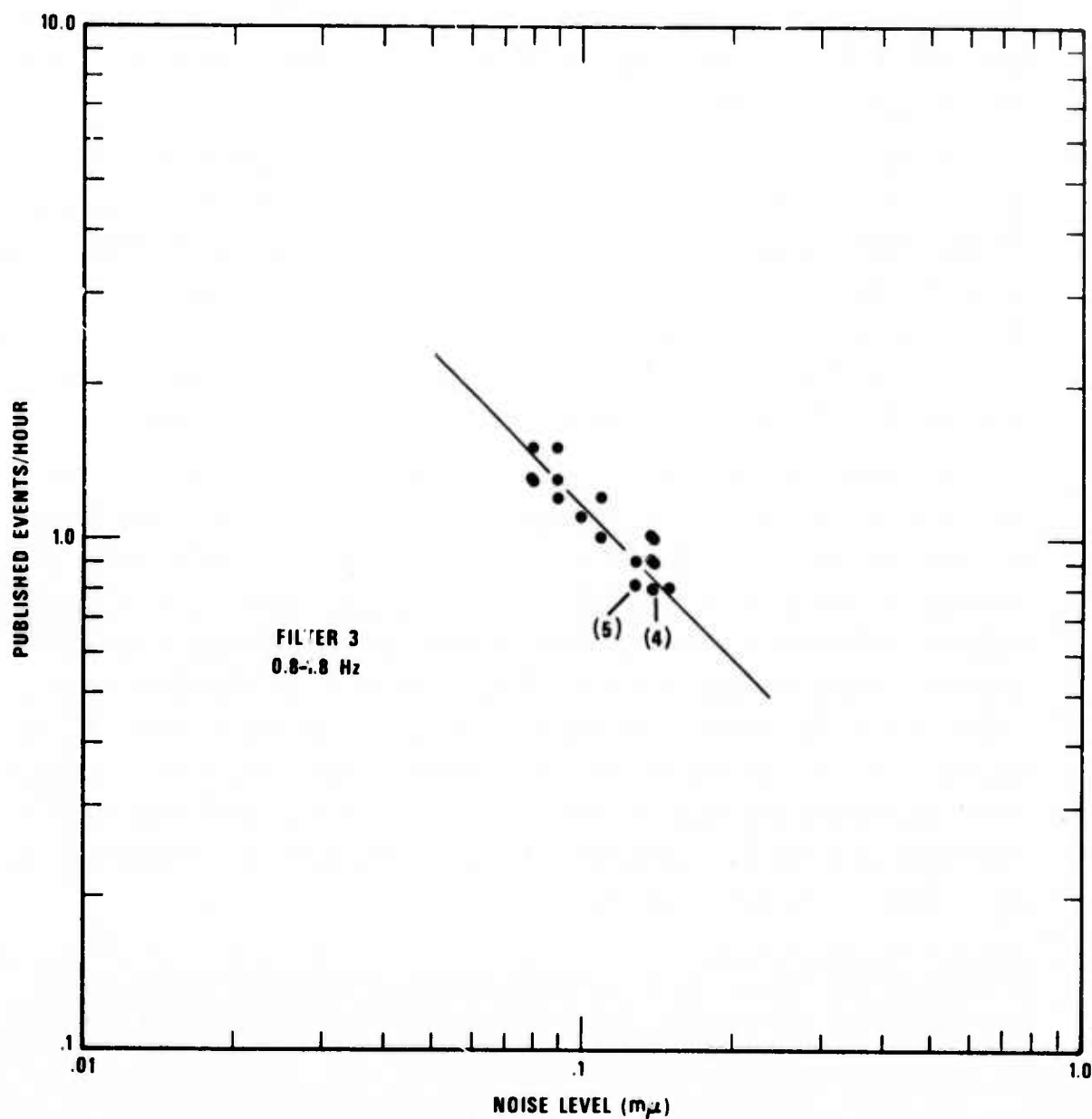


Figure 3. Published events per hour as a function of the hourly noise level for the period April 3 through June 12, 1974, during which period Filter 3, 0.8-1.8 Hz was being used. The numbers in brackets represent multiple points.

corresponds to a threshold advantage of only 0.03 magnitude units. And we must keep in mind, as mentioned in the Introduction, that the parameters  $N$ ,  $N'$ ,  $Q$ ,  $Q'$ ,  $\Delta U$  and  $P$  have not been adjusted for optimum performance with respect to filters other than 0.9-1.4 Hz. Thus even this uncertain small advantage might disappear or be reversed in an optimized system. The difference of 0.03 is much less than the rms noise difference of 0.3. The main reason is presumably that the signal has also been substantially cut down by the tighter filter.

In Table I we see various estimates of percentage efficiency of the system with the different filters. However, in light of the fact that most of the "false alarms" are regional events, the significance of these numbers is questionable. We must first develop an algorithm to eliminate problems due to regional events. Then the threshold may be lowered to begin catching "true" false alarms, and with the "true" false alarm rate held as nearly constant as possible we may compare the number of detected events.

In Figure 4 we see the derivative with respect to magnitude of the logarithm of the cumulative recurrence curves constructed from the summary bulletin for the four different filter time periods. The slope seems to be constant in each case between 4.0 and 4.8  $m_b$ . (The curvature of  $m_b \geq 4.8$  suggests that Schlein and Toksöz (1970) were correct in suggesting that a quadratic should be used to fit recurrence curves.) We therefore fit a least-squares line to the recurrence curves in the interval 4.0-4.8  $m_b$  and estimated the 50% and 90% cumulative threshold. These yield the estimated threshold differences seen in Table I. Subjectively we feel that they are consistent with the more reliable threshold differences determined from the total number of events detected.

---

Schlein, S. and Toksöz, M. Nafi, 1970, Frequency-magnitude statistics of earthquake occurrences, Earthquake Notes, Vol. XLI number 1, pp. 5-18.

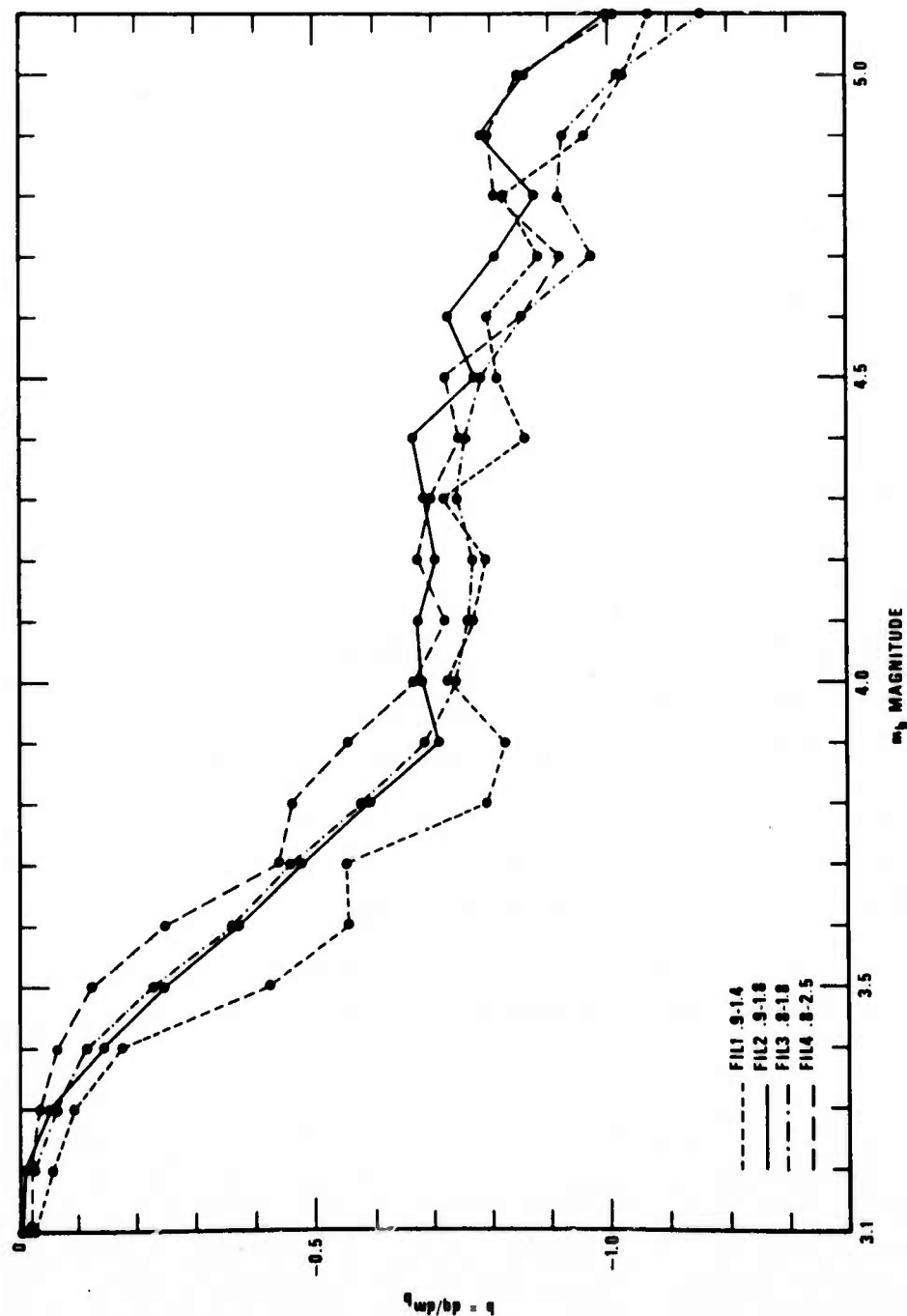


Figure 4. Derivative with respect to magnitude of the logarithm of the cumulative recurrence curves constructed from LASA bulletin data in four separate time periods in the interval March 11 through July 25, 1974. A different bandpass filter was used in each of the time periods. Least-squares lines fitted to the recurrence curves in the magnitude interval 4.0-4.8 were used to determine differential detection threshold.

#### REFERENCES

- Bungum, H. and Ringdal, F., 1974, Diurnal variation of seismic noise and its effect on detectability, NORSAR Scientific Report No. 5-73/74, NTNF/NORSAR, Kjeller, Norway.
- Chang, Andre C., 1974, A comparison of the LASA-NORSAR short-period arrays, Teledyne Geotech, SDAC Technical Report 74-5, Alexandria, Virginia. AD 003484
- Chiburis, E. F., Ahner, R. O., Chang, A. C., and Kerr, A. U., 1974a, The effect of reduced configurations at LASA on detection signal-to-noise ratios, Teledyne Geotech, SDAC Technical Report 74-7, Alexandria, Virginia. AD A004991
- Chiburis, E. F., Ahner, R. O., and Chang, A. C., 1974b, The effects of using unphased subarray sums in LASA beams on the detection performances of the array, Teledyne Geotech, SDAC Technical Report 74-14, Alexandria, Virginia.
- Dean, W., 1972, A geophysical evaluation of the short-period LASA/SAAC system, SAAC-5, Teledyne Geotech, Alexandria, Virginia. AD 745101
- IBM, August 1967, Third Quarterly Technical Report, Experimental Signal Processing System, ESD-TR-68-149, Gaithersburg, Maryland.
- Lacoss, R. T., 1972, Variation of false alarm rates at NORSAR, Semiannual Technical Summary, Seismic Discrimination, MIT Lincoln Lab, Massachusetts Institute of Technology, Cambridge, Massachusetts.
- Schlein, S. and Toksöz, M. Nafi, 1970, Frequency-magnitude statistics of earthquake occurrences, Earthquake Notes, Vol. XLI number 1, pp. 5-18.

#### ACKNOWLEDGMENTS

We are grateful to Lawrence A. Perkins and Robert R. Blandford for critically reading and editing this report.

## APPENDIX

Noise level, number of detection processor detections,  
number of events processed by the event processor and  
number of events published in the daily event summary  
bulletin.

